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ATTACK AND DEFENSE AS AGENTS IN ANIMAL EVOLUTION.

BY CHARLES MORRIS.

In considering the development of the dermal skeleton of animals, with its various modifications, we are led almost to the conception that nature has been controlled at successive periods by special ideas, each dominant during a long period, and then abandoned in favor of a new one. I have, in a previous communication to the Academy, advanced the hypothesis that in the primitive life era animals were destitute of hard parts, either external or internal, and that to this we must ascribe the lack of primitive fossils.

The development of an external skeleton, which seems to have long preceded that of an internal one, came like a new idea to nature, which was adopted almost simultaneously as it seems, though probably at considerable intervals, by the various types of life. We are quite sure that the first appearance of fossils in the rocks does not indicate the first appearance of life upon the earth. Early fossilization is due to the preservation of the dermal skeletons of animals of considerably advanced organization, and these were very probably preceded, during a long era, by soft-bodied forms of low organization. These could leave no trace of their existence, except in the case of the burrowing worms, or of impressions made by animal forms on beds of mud or other plastic material. Yet after the advent of armored animals, it is probable that the seas were still tenanted by numerous soft-bodied forms, mainly swimmers, the progenitors of the many naked ocean swimmers which still exist.

The earliest armored forms were principally surface dwellers, or sluggish swimmers. Swift-swimming armored animals came in with the fishes, and these increased in thickness and weight of armor to the end of the Devonian era. During this period all the higher forms of life seem to have acquired more or less dense dermal armor. Their agility must have been much reduced by the weight and rigidity of this armor. None but the fishes were active swimmers, and most of the armored animals were surface-dwellers.

If now we come down to a later era of life, we find in operation what seems a third idea of nature. The prevailing tendency in animal life is no longer to assume armor, but to throw off armor, and return towards the unprotected condition. This tendency was quite as marked in its operation as the others, as a hasty review will show.

In the antique type of vertebrate life, the fish, the thick armor of the primeval era has been in great part replaced by the thin scales of the Teleosteans. The Ganoids have nearly vanished. Many Elasmobranchs yet exist, but their armor never gained the dense and rigid character of the Ganoid scales. But the loss of the old condition is more particularly shown in the new forms of life. The Labyrinthodont amphibians were clothed in armor, their heads in particular being protected by hard bony plates. Modern amphibians are naked-skinned animals. The reptiles are usually scaled, but, with the exception of the crocodiles and turtles, and some few fossil types, do not seem to have ever been clothed in bony armor. In the later vertebrate classes, the birds and mammals, all defensive armor is lost, the covering of hairs and feathers being protective only against cold. Finally, in the human species, even the covering of hairs is nearly lost, and in external condition the highest form of animal life approaches the lowest.

A like tendency to pass from the armored to the unarmored condition appears in invertebrate life. In most of the invertebrates the dermal covering serves as a basis of muscular attachment, and cannot be dispensed with. The soft-bodied invertebrates of low orders, such as the worms, the medusæ, etc., are probably survivals of the primitive life condition, and may indicate the general character of pre-Cambrian life. But in the higher mollusks a very interesting variation appears. The Palæozoic cephalopods were all covered with a dense protective armor. In the Mezozoic period this class began to give way to an unarmored class, with a change in the character of its muscular attachment. To the tetrabranchiates, with muscles attached to the external shell, were added the dibranchiates, with naked surface, and an internal basis of muscular attachment. Since that period the evolutionary process has been highly interesting. The armored cephalopods have gradually disappeared, until only the Nautilus remains. The unarmored forms have rapidly increased, until they abundantly people the modern seas.

The process of modification I have here briefly indicated has another interesting feature, which may be pointed out. This is that the modification has not taken place by a simple change in the dermal structure of existing types, but that this change has been accompanied by a radical change in organic structure. The representatives of the old forms have retained much of their old surface structure. The radical variation in surface condition has been confined to new types of life.

In the case of the primitive soft-bodied animals, for instance, they have probably had representative forms throughout the whole era of life, and may be closely simulated by the soft-bodied ocean animals yet existing. The assumption of armor by certain forms was probably accompanied by a marked change in structure, the dermal variation being co-related with other important changes. Of this, of course, we cannot be sure, but in the parallel case of the discarding of armor this idea holds good. The Ganoids continue armored fishes to the present day. The prevailing thin-scaled fishes are of a new structural type. In the cephalopods we do not find a simple discarding of shells by the armored type, but the gradual disappearance of this type, and its replacement by a type of markedly different structure. In the vertebrata generally the antique types have preserved the scaled condition to a greater or less extent. It is in the new structural types, the birds and mammals, that this antique condition has been most fully discarded, and replaced by a radically distinct dermal covering. It would almost seem as if it had been impossible for any type of animal to completely dispense with a primitive structural feature except under the influence of a general organic change. In the assumption of armor the whole organic structure may have suffered a correlated change. In the discarding of armor a like radical change in structure has taken place, while the representatives of the ancient types have preserved their ancient dermal conditions.

I present these simply as a series of well-known facts. It is with the cause of these facts that I am mainly concerned. Why did animal life exist for a long period without protective covering; then adopt armor of defense, and develop it to an extraordinary degree; and finally slowly discard this armor, and return towards the unprotected condition? We have here a remarkable series of evolutionary changes. They undoubtedly had sufficient and powerful causes. What were those causes?

These we need not go far to seek. They are plainly evident. The variations described have taken place under the influence of one of the most active and efficient agents in evolution, that of the reciprocal influence of attack and defense on animal structure. To this agent in animal change there has not been given so much attention as it demands. It is, indeed, but one out of numerous agents which act to modify animal form and structure. But among these agents it has been one of the most active, efficient and unceasing.

The effort of food animals to escape from carnivorous foes, has given rise to a great variety of defensive tissues, functions, and habits. It has aided in the natural selection of armor of various kinds, of defensive weapons, of speed and flexibility of motion, of size and strength of body, of cunning and alertness, and of many other characteristics, each of evolutionary importance. And the study of animal development goes to show that these varied conditions have been assumed successively. Nature has apparently fully worked out the capabilities of one mode of defense before proceeding to another.

The effort to capture and destroy food animals has been equally important as an agent in evolution. It has caused the natural selection of weapons of offense, such as claws and teeth, of strength, swiftness, agility, alertness, cunning, and the like attributes of mind and body, together with many special habits, all of which form steps in evolution. The main cause of this advance has been the reciprocal action of these agencies. If a food animal gained some structural feature which gave it an advantage over its carnivorous foes, the latter would be at a disadvantage until they had gained equivalent features. So if a carnivorous animal gained some habit, motion or weapon which gave it an advantage in destroying, this must have acted as an incitement to a corresponding development in food animals. Natural selection has, in both cases, preserved the forms best adapted to the new conditions of attack or defense, and the carnivora and herbivora have, in a metaphorical sense, pursued each other up the ladder of evolution.

In this process now one class, now the other, may have taken the lead. If at any time the two classes were evenly balanced in powers of attack and defense, any new power of defense or escape in the food animals would undoubtedly be preserved by natural selection. It would give them an advantage in the struggle for existence, which could not be overcome until the carnivora had gained a correlated development. On the other hand any new offensive weapon or method would give the carnivora an advantage, which would render necessary some new defensive adaptation in food animals.

In this process of evolution we find several instances in which defensive appliances seem to have gained a special development, which were only slowly met by new methods of attack. Such I conceive to have been the case when the power of secretion of dermal armor was once attained, and to the high value of this defensive expedient I ascribe its rapid development. According to my theory of the case the preceding animals had been naked skinned, and the destructive weapons of the carnivora such as were adapted to the capture of soft-bodied prey. There is not a shred of evidence that any toothed forms existed preceding or during the Cambrian era, nor until well on in the Silurian. Yet toothless animals could not easily overcome animals with a strong covering of bone or other hard material. It is to this fact that I ascribe the rapid increase in number and variety of armored forms. Their armor gave them a special advantage in defense, and under this idea there is no difficulty in understanding the very rapid and general evolution of this structural feature of animal life.

In fact, as a result of the development of defensive armor, a discrepancy arose between the agencies of attack and defense. Defense had the best of it. A structural feature had been rapidly acquired, which could only be met by some corresponding new means of attack, and this new carnivorous weapon took a long time to develop.

The new weapon, through whose aid the aggressive again slowly matched the defensive appliances, made its appearance in the form of the tooth. It but slowly grew effective. The first evidence we find of teeth are the minute *conodonts*, which may or may not have had this function. Fish teeth at first appear in small and weak forms, but they gradually grow large and powerful, and well adapted for cutting and crushing. A race between aggressive and defensive powers apparently took place. Armor grew thicker and denser as teeth became more efficient. As one result of the race we have the great Devonian fishes, with their powerful armor and teeth. The toothless invertebrates probably still fed on small, unarmored prey.

In all cases, however, the most powerful animals would have little or no need of defensive armor. The armed Ganoids probably needed defense against each other. But it is likely that they were mainly defended against the great Elasmobranchs, which were the ruling tyrants of the seas, and which needed no defense beyond their osseous tubercles and spines, this type of armor permitting the utmost flexibility of motion. As Packard says of them: "Sharks and skates are engines of destruction, having been, since their early appearance in the upper Silurian age, the terror of the seas. Their entire structure is such as to enable them to seize, crush, tear and rapidly digest large invertebrates, and the larger marine members of their own class. Hence their own forms are gigantic, soft, not protected by scales or armor, as they have in the adult form few enemies." Such seems to have been the outcome of the agencies of attack and defense in the palæozoic era, a minor series of soft-bodied animals, an intermediate series of strongly armored animals, and a superior series of animals, adapted to break through the strongest defensive armor.

As a result of this evolutionary process the powers of assault and defense again became equalized, and armor lost its special value as a defensive agent. From that time forward defense seems to have adopted a new expedient, and a fresh series of modifications arose. If armor had become of little value in defense, flight remained useful. But armor impeded flight, both from its weight and the rigidity of body it produced. Thus for the development of speed, agility and flexibility of motion, it was necessary to get rid of armor; and during the whole of the later geological periods this has been the character of the evolutionary process, at least in the free-moving animals. Food animals have thrown off their armor, and trusted to speed and flexibility of motion for safety. Carnivorous animals have followed in the same direction, and got rid of their disabling armor.

If we pursue this subject further we can perceive the successive adoption of several other expedients. It is impossible to say whether flight or pursuit first aided in the development of winged animals. But it is evident that flying food animals would be nearly safe from the attacks of surface carnivora, and would gain a security which only the development of flying carnivora could overcome. The same may be said of tree-living and burrowing animals. It seems highly probable that all these expedients were first adopted in the effort to escape destruction, and that similar expedients were afterwards adopted by carnivora in their pursuit of prey. It would not be safe to declare that the various expedients mentioned were in every case first adopted by food animals, and afterwards by the pursuing carnivora, but the probability is that this was the case as a general rule.

I may briefly refer to one other and a highly important result of this evolutionary process. When powers of flight had become balanced by powers of pursuit, it is evident that this expedient, like that of armor, had lost its special utility. As a result another and final expedient began a special development. Cunning and shrewdness came into play as aids in escape. The mental powers of animals began to strongly unfold. This was the case in both classes of animals, and it is impossible to say which took the lead. In both classes cunning, concealment, reasoning powers, came into play, and blind flight and pursuit, or defense through sheer bulk and strength, became succeeded, in many cases, by the higher and more efficient agency of the mind. Instinct became less dominant in animal life; reason more dominant. In other words, the mind grew more active and varied in its operations.

The growth of this most recent animal modification is manifest in the character of the later geological life. The development of the brain becomes marked as we enter the tertiary era, and the capacity of the brain cavity steadily increases throughout this era. What is called cephalization is the most important characteristic of animal development throughout the tertiary age. In the recent era this has reached its culmination, and mental expedients have replaced physical conditions in the highest life types as the most efficient agencies of attack and defense.

Thus we seem to perceive four successive ideas emerging into prominence in the development of the animal kingdom. In the primeval epoch it is probable that only soft-bodied animals existed, and the weapons of assault were the tentacle, the thread cell, the sucking disk, and the like unindurated weapons. At a later period armor became generally adopted for defense, and the tooth became the most efficient weapon of attack. Still later armor was discarded, and flight or concealment became the main methods of escape, and swift pursuit the principle of attack, while claws were added to teeth as assailing weapons. Finally mentality came into play, intelligence became the most efficient agent both in attack and defense, and a special development of the mind began. As a culmination of the whole, we have man, in whom mentality has replaced all other agents in the struggle for existence. But side by side with man all the other types exist, the soft-bodied, the armored, the swift-moving, and those in which cunning precedes the higher mentality. In the existing conditions of life upon the earth we have an epitome of the whole long course of evolution.